UNITED STATES PATENT APPLICATION

OF

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FOR

RADIO NETWORK ROUTING APPARATUS

5 **TITLE OF THE INVENTION**

RADIO NETWORK ROUTING APPARATUS

BACKGROUND OF THE INVENTION

10 1.   <u>Field of the Invention</u>

The present invention relates to a radio network routing apparatus, and more particularly, to a protocol which reduces the amount of protocol traffic in mobile network routing.

2.   <u>Description of Related Art</u>

15 Mobile networks typically use radios to communicate, but such radios are relatively slow data paths, as compared to wired networks or networks connected with fiber-optics.

In computer networks, the Open Shortest Path First (OSPF) routing algorithm is used for synchronizing the communication

20 information in a computer network. The OSPF routing protocol, is a type of link-state protocol. A detailed discussion of link-state routing, including the OSPF protocol is included in Chapter 5 of <u>Routing in Communications Networks</u> by Martha Steenstrup and Chapter 5.2.2 of <u>Computer Networks</u> by Andrew S.

25 Tanenbaum. OSPF provides a method of synchronizing databases in computer network " routers."   In OSPF, the router periodically advertises information describing its own database data (also referred to, herein, as link state data) to a

5   neighboring router and includes a sequence number that the

neighboring router can use to detect old or duplicate

advertisements. The router increases the sequence number when

it originates a new version of the advertisement. Thus, a

larger sequence number signifies a more recent advertisement.

10 The OSPF routing algorithm is also described in U.S. Patent No.

5,913,921 (Tosey et al.) and U.S. Patent No. 5,881,246 (Crawley

et al.).

Mobile networks have been unable to use standard OSPF protocols

to exchange internet routes and addresses. This is primarily

15 due to the fact that OSPF protocols require constant route

discovery through the use of HELLO messages. HELLO messages

are packets of information dispersed by each node throughout

the network to determine network topology. This HELLO traffic,

alone, can potentially utilize all of the message capability

20 (also referred to, herein, as " bandwidth") of a mobile

network having numerous nodes.

For example, a network consisting of four radio nodes (i.e.,

NODE A, NODE B, NODE C, AND NODE D) would generate several

HELLO messages.   NODE A would send a HELLO message to each of

25 NODES B, C, and D; NODE B would send a HELLO message to each of

NODES A, C, and D; NODE C would send a HELLO message to each of

NODES A, B, and D; and NODE D would send a HELLO message to

each of NODES A, B, and C. Each such HELLO message sent by a

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5   radio node must be answered with a reply HELLO message. Thus,

the resulting number of HELLO messages (HM) for a network with

N nodes can be determined by the following formula:

$$HM = N \times (N - 1) \times 2$$

10   Accordingly, a network with four nodes would generate 24 HELLO

messages. A network of 100 nodes would produce 19,800 HELLO

messages. Clearly, the generation of so many HELLO messages in

OSPF protocols has made the use of such protocols in mobile

networks unfeasible.

SUMMARY OF THE INVENTION

15   Among the several objects of the present invention, is to

reduce the amount of protocol traffic and, thereby, reduce

bandwidth usage. Another objective of the present invention is

to keep protocol messages as short as possible.

20   According to a first aspect of the present invention, each

router in a radio network having a plurality of routers

comprises a memory storing a routing table, and a receiver for

receiving link state information from the network. A processor

is provided for (i) determining, responsive to the received

25   link state information forwarded to the router, a status of

connections in the network, (ii) generating network topology

information based on the determined connection status

5   information, (iii) placing the generated network topology

information in said routing table, and (iv) transmitting the

network topology information in the routing table to at least

one other router in the network.

According to a second aspect of the present invention, a method

10   of distributing network topology information in a radio network

that includes a plurality of routers comprises the steps of

receiving link state information of the network that is

forwarded to each router; determining connections of devices in

the network in the receiving router responsive to the received

15   link state information forwarded to the router; and collecting

the determined device connection information to generate

network topology information in the receiving router. The

generated network topology information is placed in a routing

table of the receiving router, and the network topology

20   information is retrieved from the routing table.

According to a third aspect of the present invention, a routing

system in a radio network having plural routers comprises a

plurality of routers each including a receiver for receiving

link state information from the network in a message issued to

25   the plurality of routers. Each router also includes a

processor, responsive to the received link state information,

for (i) determining router connection information in the

network, (ii) collecting the determined router connection

5   information (iii) generating network topology information from

the collected router connection information, (iv) storing the

generated network topology information in a routing table, and

(v) retrieving the network topology information in the routing

table and forming it into a link state message to be broadcast

10   to at least one other router in the network.

According to a fourth aspect of the present invention, a

computer executable software code stored on a computer readable

medium is used for distributing network topology information in

a radio network that includes a plurality of routers. The code

15   comprises code for receiving link state information of the

network that is forwarded to each router; code for determining

connections of devices in the network in the receiving router

responsive to the received link state information forwarded to

the router; and code for collecting the determined device

20   connection information to generate network topology information

in the receiving router. Code is included for placing the

generated network topology information in a routing table of

the receiving router, and code is provided for retrieving the

network topology information from the routing table.

25   The foregoing and other objects, advantages, and features of

the present invention will become more apparent from the

following detailed description of the preferred embodiments

5   taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a mobile communications station.

Fig. 2 is a diagram illustrating a radio network configuration in accordance with the present invention.

10   Fig. 3 is a diagram illustrating routing tables for each router in the radio network of Fig. 2.

Fig. 4 is a flow chart illustrating the routing method of the present invention.

Fig. 5 is a diagram illustrating a " backbone" network of the
15   present invention.

Figs. 6A and 6B are diagrams of a packet radio network with and without a designated router.

Fig. 7 is a flow chart of the ROSPF processing method.

20   **DETAILED DESCRIPTION OF THE**
                            PREFERRED EMBODIMENTS

The present invention relates in substantial part to a radio open shortest path first (ROSPF) protocol in mobile networking routing. In particular, this protocol (which can be used in
25   Intranet routing) involves dramatically reducing the amount of

5   protocol traffic and shortening the length of each protocol

message.   The reduction in protocol traffic facilitates the use

of ROSPF protocols in mobile networks.

Typically, HELLO messaging is the only way that the radio

learns about other nodes in the system.   However, the current

10 invention does not require such extensive messaging.   Rather,

the ROSPF protocol utilizes the current forwarding table of a

radio node to learn about the other nodes in the system.   The

mobile routing protocol initiates link state flooding every

second or so in a controlled manner to determine the

15 connectivity topology of the network.   Flooding is known to

those of ordinary skill in the art, for example, as described

in Steenstrup's Routing in Communications Networks.   The

flooding procedure is used for distributing link-state

advertisements (LSA) (also referred to, herein, as link-state

20 packets, LSP) throughout the routing domain.   When the

connectivity of the network changes, a new LSA describing the

change must be created and flooded to all of the other nodes.

There is no need for reply messaging.

The preferred embodiments will be described with respect to a

25 wireless mobile communications station and to a network formed

by a plurality of similar mobile stations.   However, the

present invention is not limited to the wireless mobile

communications field.   Instead, the invention is applicable to

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 5   many other types of networks, including cellular telephone

      systems, wireless metropolitan area networks, and so forth.

      Figure 1 depicts a wireless communications station 2. The

      mobile station 2 includes a central processing unit (CPU) 3, a

      memory 4 (suitable for storing computer executable software

10   therein), a power supply 5, a transceiver 6 (e.g., a

      transmitter and a receiver), RAM 7, and ROM 8. Alternatively,

      the mobile station 2 may include more than one transmitter

      and/or more than one receiver. The mobile station 2 can also

      include an Ethernet interface, as well as other interfacing

15   ports. With these arrangements, the mobile station 2 is able

      to simultaneously communicate with more than one station.

      Communication with multiple stations can occur, for example,

      through different channels (or " communication links"), and/or

      by transmitting specific identifying information (or " coded

20   information") for each intended source or target.

      Figure 2 is a schematic diagram of radio nodes in a wireless

      network according to the present invention. Five routers 10,

      12, 14, 16, and 18 comprise the wireless network. Established

      channels or data communication links connecting the various

25   routers are designated by reference characters 20-26. The

      reference characters 20-26 also represent the cost of

      communicating along each respective channel (i.e., the cost of

      sending data traffic over each link). For example, the cost of

                                   8

5   sending data traffic from node A to node B is 20.

While Figure 2 illustrates a particular interconnection of the
various stations shown, it should be understood that this
configuration of connections is not pre-determined and that
other patterns of connections might easily arise in accordance

10   with the present invention. Moreover, the pattern of
connections can change during operation, both to accommodate
the introduction of new stations and to allow for the
withdrawal or movement of one of the nodes. The mode of
operation of each router is controlled by an embedded

15   microprocessor (e.g. the CPU) and the method of operation
described herein is intended to be implemented automatically by
the programming of the microprocessors.

Figure 3 is illustrative of the routing tables for each node in
the network. Upon collecting the network topology information,

20   each router builds a routing table (stored in memory)
containing the acquired data. The routing table includes
information such as the identity of the relevant router, a list
of the router's operational links, the cost of each operational
link, the identity of the node to which the router connects,

25   and other such information.

The routing domain for the network in Figure 2 is displayed in
Figure 3. The routing tables 101, 121, 141, 161, and 181

5   correspond to routers 10, 12, 14, 16, and 18, respectively.

The routing table 101 for router 10 (radio node A) advertises

three active interfaces: one connecting to router 12 (node B)

with a cost of 20, one connecting to router 14 (node C) with a

cost of 24, and one connecting to router 18 (node E) with a

10   cost of 23.

Numerous other categories of information may be stored in these

routing tables.   For example, the sequence number, which is

used to determine the most up-to-date instance of data in the

routing table, can be stored. Additionally, the age of a

15   routing table can be stored so as to indicate when defunct data

should be discarded and when the radio node should refresh its

router. Another helpful type of data to be stored is the

checksum of an advertisement's contents which assists in

guarding against data corruption.

20   Adding more detailed and voluminous data in the routing table

can facilitate more sophisticated routing-table calculations

which are used for efficient message forwarding in a mobile

network.

The topology information is collected by the routing protocols

25   using minimum bandwidth, so that it does not need to be

collected again by ROSPF or any type of HELLO messaging.

In the overall method, shown in Figure 4, each radio node is

5   activated initially by the POWER ON step S1. A delay of random

    duration, e.g. from 1 to 60 seconds, is provided as indicated

    in step S2. After the delay, the router executes the receiving

    step S3 for receiving link state information of the network

    that has been forwarded to the router.

10 Subsequently, the determining step S4 is activated and is

    responsive to the received link state information forwarded to

    the router for determining connections in the network. If

    there are other accessible nodes in the network (step S5), then

    the network connection information is collected by the

15 collecting step S7 and placed in the routing table in the

    placing step S8.

    However, if there are no accessible nodes in the network, then

    the controlling step S6 is executed. The controlling step S6

    determines how often the router will attempt to gather and

20 distribute network topology information. The controller can be

    programmed so that it controls the frequency of this procedure

    based on a myriad of factors. For example, the flooding can

    occur periodically at regular intervals, e.g. every minute,

    every 10 minutes, every hour, etc. The controller can also

25 activate this procedure in response to a significant event,

    such as when a neighboring node leaves or joins a network.

    In the case wherein there are other accessible nodes in the

5   network and the data regarding these other nodes has been

stored in the routing table, a determination is made in step S9

regarding whether there are messages that need to be forwarded

to other nodes in the network. If the response to the inquiry

in step S9 is affirmative, then the retrieving step is executed

10   in step S10. Once that is complete, the controlling step is

executed in step S6. Based on the frequency with which the

controlling step is activating the overall procedure, the

process will begin again at the appropriate time.

However, if the response to the inquiry in step S9 is negative,

15   then resignation from the network occurs in step S11.

The ROSPF protocol has a functionality like the OSPF protocol.

However, in the ROSPF protocol, the " behavior" of the router

has been modified to eliminate enormous quantities of traffic

that would otherwise " clog" a large, multi-hop, low bandwidth

20   network, such as a packet radio network. ROSPF allows a large

packet radio network to become an internet protocol (IP)

backbone. As explained in further detail below, the ROSPF

protocol defines a parasitic relationship between two routing

protocols.

25   Figure 5 illustrates a backbone network that is arranged using

OSPF. The purpose of OSPF is to compute routes to IP networks.

In an initial step of OSPF, each router discovers its

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5   neighbors. This is accomplished using the Hello protocol. It

not only discovers neighbors but it also elects a

" spokesperson" for the network called the designated router.

Secondly, each router constructs Link State Packets (LSPs) that

contain the IDs and costs of the links to its neighbors.

10 Next step, the LSPs are transmitted to all the other neighbors,

via the designated router using the link state flooding

process. Each router stores the most recently generated LSP

from each of the other routers, and creates a link state

database. The link state database defines the topology (i.e.,

15 the configuration of the nodes and links) of the network and

the cost of each link.

Finally, each router uses the link state database to compute

routes to each destination.

The network illustrated in Figure 5 depicts a backbone network

20 created by OSPF. The backbone network provides the means for

connecting IP networks X, Y, and Z. Router 193, which is

depicted as the designated router, exchanges LSPs with the

other two routers. Router 191 and router 192 do not have the

capability to exchange LSPs with each other directly.

25 However it is feasible to use OSPF to create an IP backbone

only when the number of OSPF routers that are attached to the

5 backbone network is small in comparison to the bandwidth of the backbone network. Otherwise, in a case when the backbone network is a large-scale packet radio network with limited link bandwidth and a large number of nodes, then the OSPF protocol and LSP traffic will exceed the capacity of the backbone

10 network.

ROSPF uses two primary mechanisms to either reduce or eliminate these traffic loads.

The first mechanism is the elimination of the hello protocol that is an aspect of OSPF. When the backbone network is a

15 packet radio network with an Intranet routing algorithm, and every router in this network is running OSPF, then the Intranet routing algorithm already has information that is equivalent to the information that would be obtained by the OSPF hello protocol. In this particular case, the hello protocol is

20 redundant and can be eliminated. However, this redundancy would not exist if the backbone network consists of, for example, an Ethernet LAN or an X.25 network. Accordingly, ROSPF can primarily be used in conjunction with a network that has an Intranet routing algorithm. The Intranet is an

25 independent entity that provides information to the OSPF protocol, while ROSPF defines the parasitic relationship between the Intranet and the OSPF protocols.

5   The second mechanism employed by ROSPF is the elimination of

designated routers. Designated routers define the way that

link state packets are flooded. They flow from a given router

to the designated router and then fan out to reach all the

other routers. In a large scale network, the flow of link

10   state packets through the designated router can make it a " hot

spot" as illustrated in Figure 6A, wherein designated router

202 denotes the hot spot of the network. In a packet radio

network with an Intranet routing algorithm, the backbone

network topology includes a connected graph, as shown in Figure

15   6A. The Intranet forwarding tables define the routes that

packets take through the network.

However, in ROSPF there is no designated router and IP LSPs are

exchanged by each node with its Intranet neighbors. In

essence, IP link state packets flow through the network like a

20   rumor in a community, or a ripple in a pond. As such, ROSPF

eliminates the designated router hot spot.

The ROSPF/Intranet interface enables the Intranet to provide

ROSPF with two lists: the next-hop list and the census list.

The next-hop list is used to define OSPF adjacencies (i.e.,

25   one-hop radio neighbors). The census list is used identify all

radio routers on the network. Deltas (differences in these

lists) are used to quickly detect deceased routers.

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5   The ROSPF processing method is illustrated in Figure 7.   In

step S20, ROSPF queries the Intranet.   The next-hop list is

processed in step S21.   In this step the network is examined

for deltas to build OSPF adjacencies with new neighbors and

terminate OSPF adjacencies with missing neighbors.

10   The census list is processed in step S22.   The census list

defines all of the nodes that are currently in the network.

The deltas are computed by comparing the new list with the old

list.   ROSPF ignores the new nodes, but identifies the nodes

that have " dropped off" the list.   For each node that is no

15   longer on the list, ROSPF marks the IP link-state that the node

advertised as irrelevant and computes an updated IP forwarding

table.   Census list processing allows ROSPF to quickly detect

" dead" routers.

The ROSPF process is cyclical and begins again at step S20.

20   The frequency of the Intranet queries can be periodic,

predetermined, or set by any number of variables.

While the present invention has been described with respect to

what are presently considered to be the preferred embodiments,

it is to be understood that the invention is not limited to the

25   disclosed embodiments.   The present invention is intended to

cover various modifications and equivalent arrangements

included within the spirit and scope of the appended claims.

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5   For example, the radio network has been described as having

five radio communication nodes (Figures 2 and 3). However, the

network can include any number of radio and wired links. Also,

as will be appreciated by those skilled in the art, the methods

and control logic, as described herein, can be embodied in a

10 programmable computer or computer executable software that is

stored on computer readable media, for example, on a floppy

disk, RAM, ROM, a hard disk, removable medium, flash memory,

memory sticks, optical medium, magneto-optical mediums, etc.

Additionally, the described methods, structure, and functions

15 are directed to wireless mobile communications stations that

automatically configure themselves in a mobile communications

network, with each mobile station directing its respective

affiliation. However, control of such configurations could be

centralized to cluster heads, for example, which would then

20 direct affiliation on a network level to optimize the network.

Furthermore, the above methods and structure are not limited to

wireless communications networks, but may be employed by any

system wherein there is an Intranet protocol to interface with

the ROSPF protocol.